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# LIGHTNING PROTECTION for the FARM

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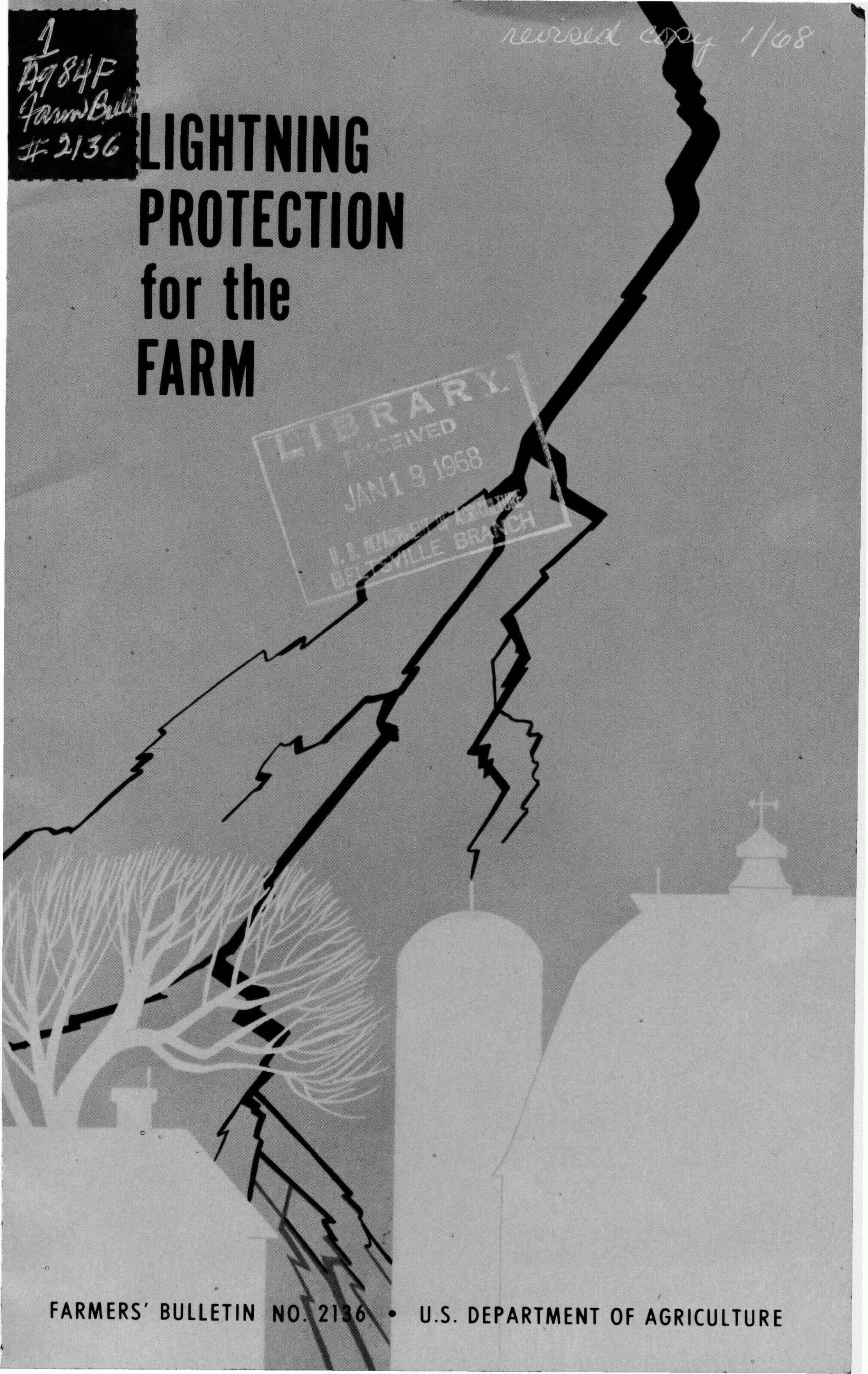

FARMERS' BULLETIN NO. 2136 • U.S. DEPARTMENT OF AGRICULTURE

**Lightning-protection systems should be planned and installed only by persons who have the necessary training and equipment.**

**The farmer or homeowner should have a working knowledge of the principles of lightning protection so that he can determine his lightning-protection requirements, discuss his plans with installation experts, survey the completed installation systematically, and make periodic inspections of the installation.**

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# LIGHTNING PROTECTION For the Farm

By MERRILL S. TIMMINS, JR., *Architect*
*Agricultural Engineering Research Division*
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Lightning—one of the most destructive forces of nature—is a particularly dangerous and costly peril on the farm.

- Four out of every five human deaths or injuries from lightning occur in rural areas.
- Lightning is a major cause of farm fires. Barns, loafing sheds, and other livestock buildings are particularly vulnerable. Damage to farm buildings runs into tens of millions of dollars every year. Appliance and equipment losses total additional millions.
- Lightning bolts cause more than 80 percent of all livestock losses due to accidents.

Lightning protection can prevent or greatly reduce this danger to life and property. A properly designed, installed, and maintained lightning-protection system affords almost 100-percent protection to a building. And, in most States, lightning protection reduces the cost of fire insurance on buildings.

[1] The author gratefully acknowledges the valuable suggestions and information contributed by the Lightning Protection Institute (2 N. Riverside Plaza, Chicago, Ill. 60606) and The National Fire Protection Association (60 Batterymarch St., Boston, Mass. 02110).

## THE NATURE OF LIGHTNING

Lightning is electric current with tremendous amperage (rate of flow) and tremendous voltage (pressure).

Ordinary house current is 110 to 240 volts, with 100 amperes available at the main service panel. One-tenth amp is enough to kill if the current passes through the body or to start a fire if there is a short in the wiring. A lightning bolt's amperage may be 2,000 times as great.

House current voltage would have to be increased a thousand times before the current could jump even 1 foot through the air. Lightning's 10 million to 100 million volts is so great that a bolt may leap a mile or more through the air.

House current consists of continuous electric impulses following a controlled path of low-resistance wires. Lightning is a gigantic uncontrolled split-second surge of electric current that may deliver enough energy in that instant to lift a large ocean liner 6 feet into the air.

Electricity is always in the air. Normally there is a balance of positive (plus) charges and nega-

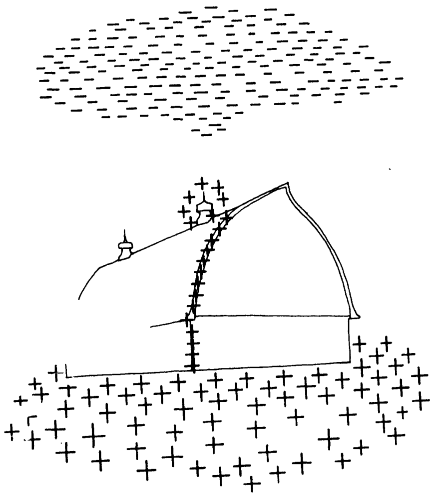


*Figure 1.*—When a storm builds up, negative charges accumulate in the base of clouds. Positive charges accumulate in the top part of clouds, in the ground, and in objects over which the clouds pass. The eventual result may be a lightning bolt.

tive (minus) charges. But when a storm builds up, this balance is disrupted. Violent air currents and temperature differences separate the charges. Negative charges usually build up in the lower parts of clouds, and positive charges accumulate in the ground and upper parts of the clouds. In electricity, opposite charges attract; as the thundercloud moves, the ground charge follows along below like a shadow. Some of the positive ions swarm into and around objects over which the cloud passes (fig. 1). When the voltage becomes great enough to push the current across the gap of air between the two buildups, the result is a lightning bolt.

Lightning strikes trees, buildings, or other objects because the materials in them are better electrical conductors (easier paths to ground) than air. In a grove of trees or a cluster of buildings, lightning is most likely to strike the object that is (1) the best conductor, (2) nearest the approaching cloud, or (3) the tallest one in the group.

Lone trees and farm buildings are prime lightning targets, because they provide the only "ladder" in the area for the ground charges to climb nearer the cloud charges. A man plowing a field—particularly if he is on a hill—is vulnerable because the metallic plow in the ground and the tractor form an excellent lightning conductor. One spring, five Iowa farmers were killed by lightning bolts while plowing during a 3-week period of electrical storms.

A lightning bolt is classed as either "hot" or "cold" according to whether or not its flow of current lasts long enough to start a fire in flammable materials. About two of every three bolts are cold, but there are still enough hot bolts to make lightning the chief cause of fire.

When a hot bolt sets fire to a barn, the barn will usually burn to the ground. The average farm house is not so much of a tinderbox and, because the bolt jars the occupants, the fire is usually detected immediately. Two of every three houses are saved from total destruction.

## PRINCIPLES OF LIGHTNING PROTECTION

All important farm buildings should be protected against lightning. Minor buildings, trees, and wire fences may also require protection.

Lightning can enter a building in four ways:

1. By a direct stroke to the building.
2. By striking a metal object, such as a television antenna, cupola, or track, extending out from the building.
3. By striking a nearby tree and leaping over to the building to find a better path to ground.
4. By striking and following a power line or an ungrounded wire fence attached to the building.

The bolt will generally follow a metallic path to ground (and from the ground up) (fig. 2, *top*). At points along that path, the main bolt may leap from the wiring to the plumbing, for instance. Or, parts of the current may sideflash to objects such as appliances, water lines, or even a person or an animal.

Lightning-protection systems must be designed (1) to provide a direct, easy path for the bolt to follow to ground, and (2) to prevent damage, injury, or death as the bolt travels that path (fig. 2 *bottom*). All points that the bolt is likely to strike and all objects to which the current might sideflash must be protected.

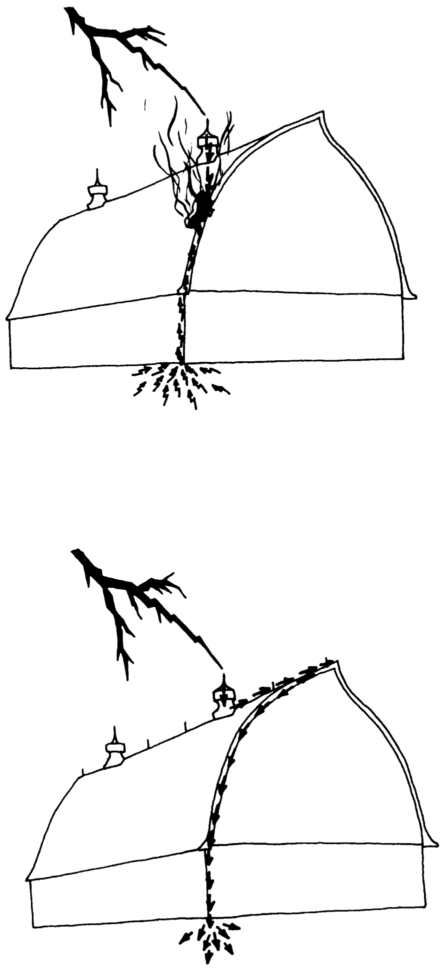


*Figure 2.*—On unprotected buildings (top), a lightning bolt may follow any path of low resistance to ground and cause damage anywhere along that path. On protected buildings (bottom), the lightning conductors provide a direct path to ground.

## PROTECTION FOR BUILDINGS

Two types of lightning-protection systems are used on buildings—concealed and semiconcealed. They differ in location of the components.

A system consists of five principal parts—air terminals (rods or points), main conductors, branch conductors, arresters, and ground connections or rods.

Secondary service arresters and arresters for television lead-in wires are recommended for more protection.

### Concealed and Semiconcealed Systems

Concealed lightning - protection systems are usually installed during

construction of the building (figs. 3 and 4). The conductors are run inside the building's framing, and the ground connections are made through the base of the wall directly into the ground. The only visible parts are inconspicuous terminal points—small, slender, and neutral in color.

Semiconcealed systems are installed on existing buildings. Inconspicuous terminal points are also used in these systems. The conductors are placed behind downspouts and other parts of the building to conceal them as much as possible.

Concealed systems stand less chance of being damaged by the elements. Semiconcealed systems are easier to inspect.

## Air Terminals

Air terminals are pointed metal rods or tubes that are installed at high points of the building (fig. 5). Their purpose is to take any lightning bolt that may strike in the immediate area.

Ornamental rods or terminal points are available. Shorter than the old-fashioned type and architecturally modern in design, they can be attractive features on a building.

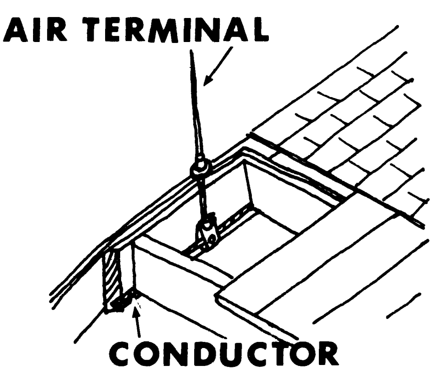



*Figure 3.*—Air terminals are the only visible parts of concealed lightning protection systems.

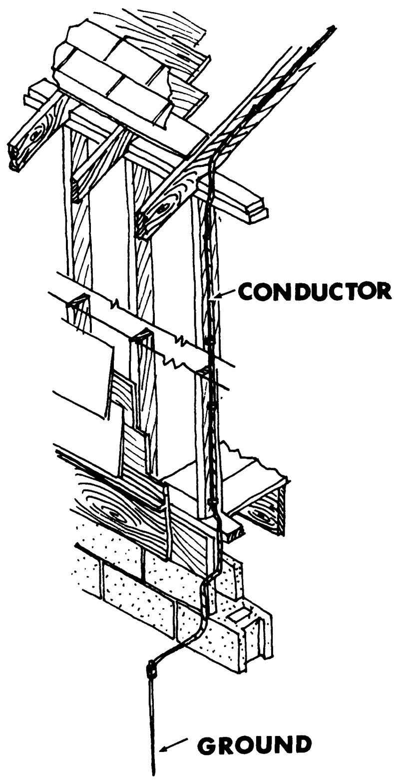



*Figure 4.*—In concealed lightning protection system, the ground connections are made through the base of the building wall.

Terminals are usually 10 to 24 inches long (high) but may be longer. Contour and slope of the roof determine the length of terminal to use. Shorter lengths are preferred because they are less conspicuous. Terminals must be as stiff and heavy as a copper tube having a wall thickness of 0.032 inch and a diameter of $\frac{5}{8}$ inch.

Terminals less than 24 inches high are spaced a maximum of 20 feet apart along roof ridges, railings, and parapets; those 24 to 36 inches

high are spaced a maximum of 25 feet apart.

Air terminals more than 24 inches in height must be supported by a suitable brace, attached no lower than the midpoint of the terminal.

A terminal should be installed within 2 feet of each gable end of a roof. All chimneys, dormers, ventilators, flagpoles, towers, water tanks, and other projections should have one or more terminals. Silos and towers with flat roofs should have two or more. Towers similar to those used in forest or wooded areas should also receive lightning protection.

Terminals on chimneys must be coated with lead to prevent corrosion by smoke fumes (fig. 6).

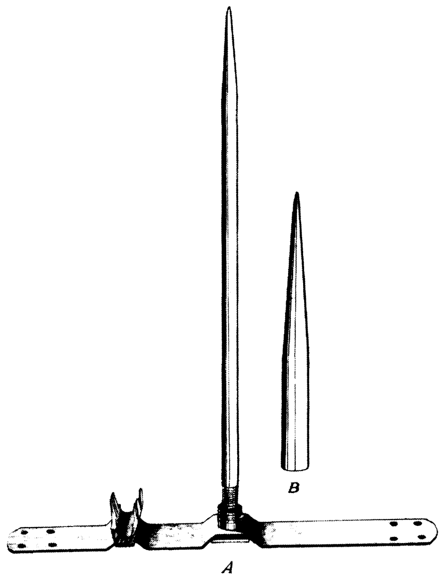



*Figure 5.*—Common types of air terminals are (A) screw-in mounting and (B) screw-on mounting.

To insure complete and effective lightning protection—

• Have the work done only by an experienced installer. Installation of a lightning-protection system *is not a do-it-yourself job.*

• Don't be hurried into buying a lightning-protection system. It is an installation of vital importance and should be bought from a responsible company.

• Check and record the identification of the lightning-protection salesman. Verify his connection with a responsible company.

• Obtain the names of three customers for whom the company has made installations and check with them as to quality of the work and other details.

• Don't allow the work to begin without proof that the company or the individual doing the work carries Workmen's Compensation Liability Insurance.

• Personally verify that the rods, cables, ground rods, and connectors used in the system carry the U/L (Underwriters' Laboratories, Inc.) label, and that the lightning arresters carry the manufacturer's name.

• Make sure that you sign an application blank for a U/L "Master Label." The installer should have the form. You will receive the "Master Label" plate (4 by 2½ inch brass plate) in the mail from Underwriters' Laboratories, Inc. through the manufacturer of the equipment.

• Insist on a contract listing all of the parts described.

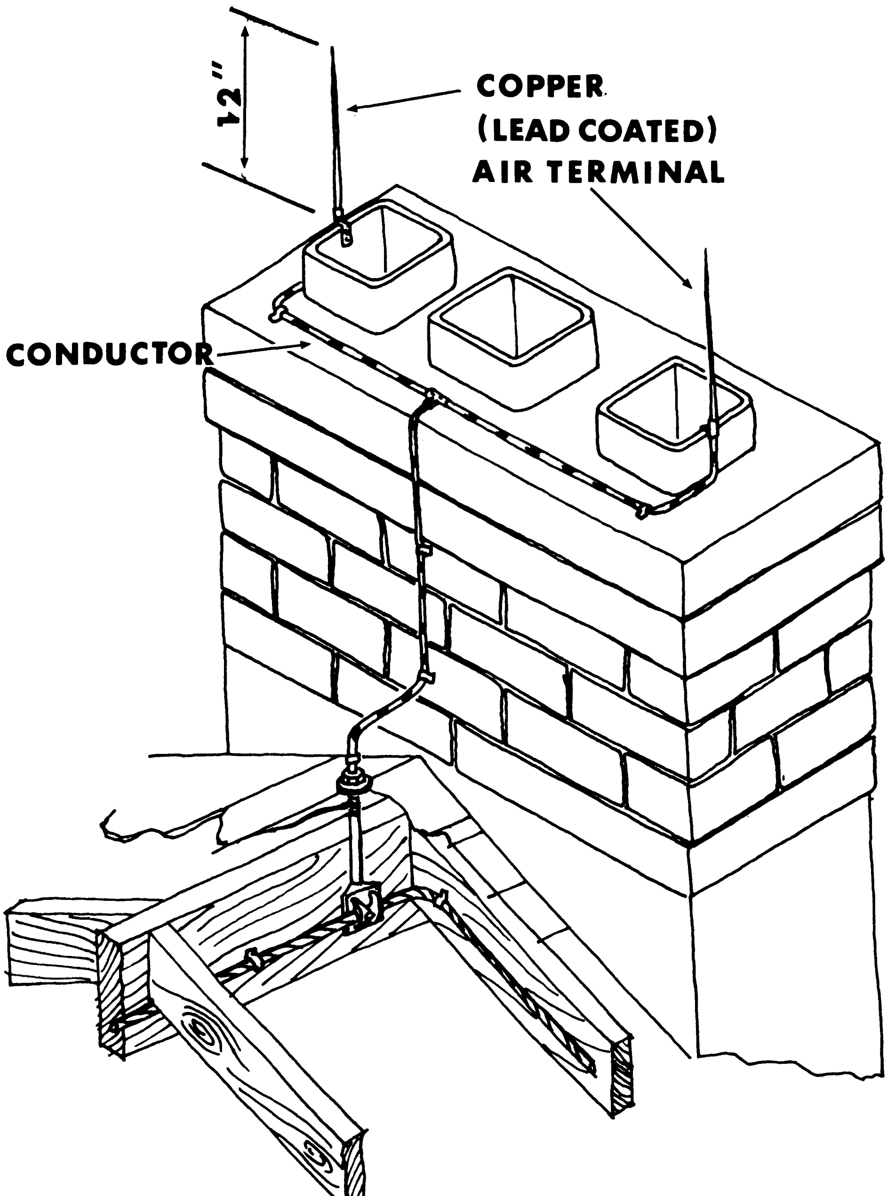



*Figure 6.*—Lead-coated air terminals are used on chimneys to protect against corrosion.

## Main Conductors

The main conductors connect air terminals with each other and with grounds. Their purpose is to conduct the lightning bolt safely from the point struck to the ground. All branch conductors are connected to them.

Conductors should be made of copper or aluminum; galvanized steel is no longer recommended. Whenever dissimilar metals are joined, bimetal connectors must be used to prevent corrosion.

The flexible cable form of conductor is more popular than the rod, because it is easier to install and has fewer joints to interfere with the conducting of electricity (fig. 7).

Only copper cable should be used where salt air is common; aluminum will corrode.

Conducting capacity of a conductor depends on its weight. Minimum acceptable weight per thousand feet is: copper, 187.5 pounds, and aluminum, 95 pounds.

Conductors should be installed in straight lines between air terminals and down to grounds. Unavoidable bends should have a radius of not less than 8 inches.

Conductors should be joined with noncorrosive fittings that will provide continuous electrical connection without soldering. Fasten conductors with strap fasteners or with special masonry anchors spaced 3 feet apart (fig. 8).

## Branch Conductors

Branch conductors are used to connect all structural metal parts of

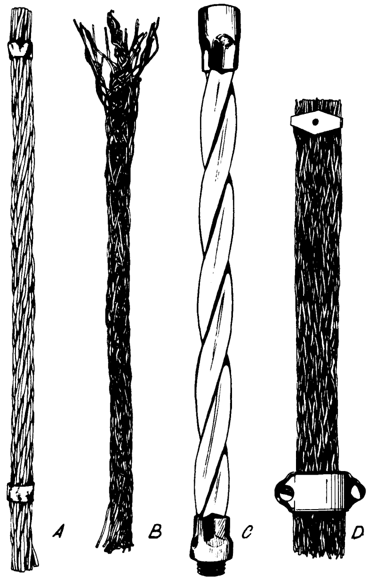



*Figure 7.*—Common types of conductors are (A) twisted cable, (B) braided cable, (C) star-section rod, and (D) flat cable.

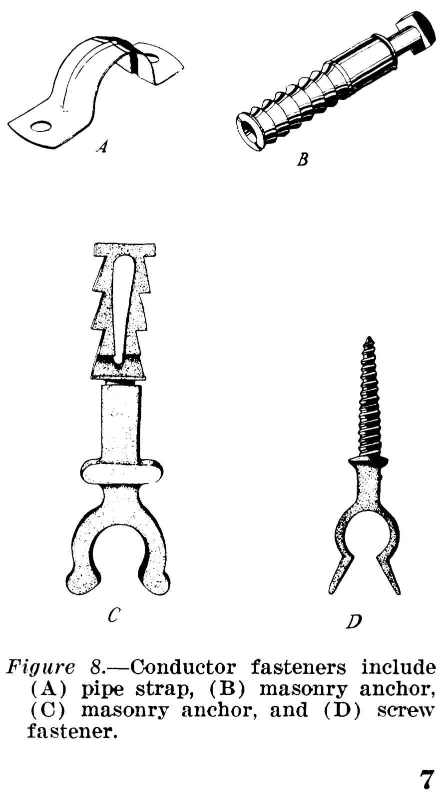



*Figure 8.*—Conductor fasteners include (A) pipe strap, (B) masonry anchor, (C) masonry anchor, and (D) screw fastener.

the building and other possible metal bodies of conductance and inductance to the lightning-conductor system.

Metal bodies of conductance are those metal objects attached to or part of the building that may be subject to direct lightning discharges because of their exposure or their proximity to the lightning conductor. They may include hay tracks, high eave troughs (above the second floor level), metal roofing, metal ridge rolls, metal ventilators, metal chimney extensions, television antennas, wire fences, clothes wires, guy and supporting wires, and litter tracks (figs. 9 and 10). Unless in direct contact with the lightning conductor or otherwise adequately grounded, these metal objects must be connected to the lightning-conductor system. If they are not connected, lightning could flash across the gap.

Metal bodies of inductance are those metal objects that may at times build up a charge opposite to that of the ground or the grounded lightning conductor. If 6 feet or less from the lightning conductor, they may induce a spark across the intervening gap. They must be connected to the lightning-conductor system. Metal bodies of inductance may include door tracks, storage tanks, low eave troughs (below the second floor level), and downspouts. Interior ones may include stalls and stanchions, milking machine lines, water lines, I-beams of extended length, steam or gas pipes, litter tracks, gutter cleaners, conveyors, and extended metal ducts (figs. 9 and 10).

If the lightning conductor has been grounded to a metal water pipe in the building, metal bodies of inductance may be connected to the water pipe system, to the nearest lightning conductor, or to another metal object already connected. Use the shortest path to the lightning-protection system.

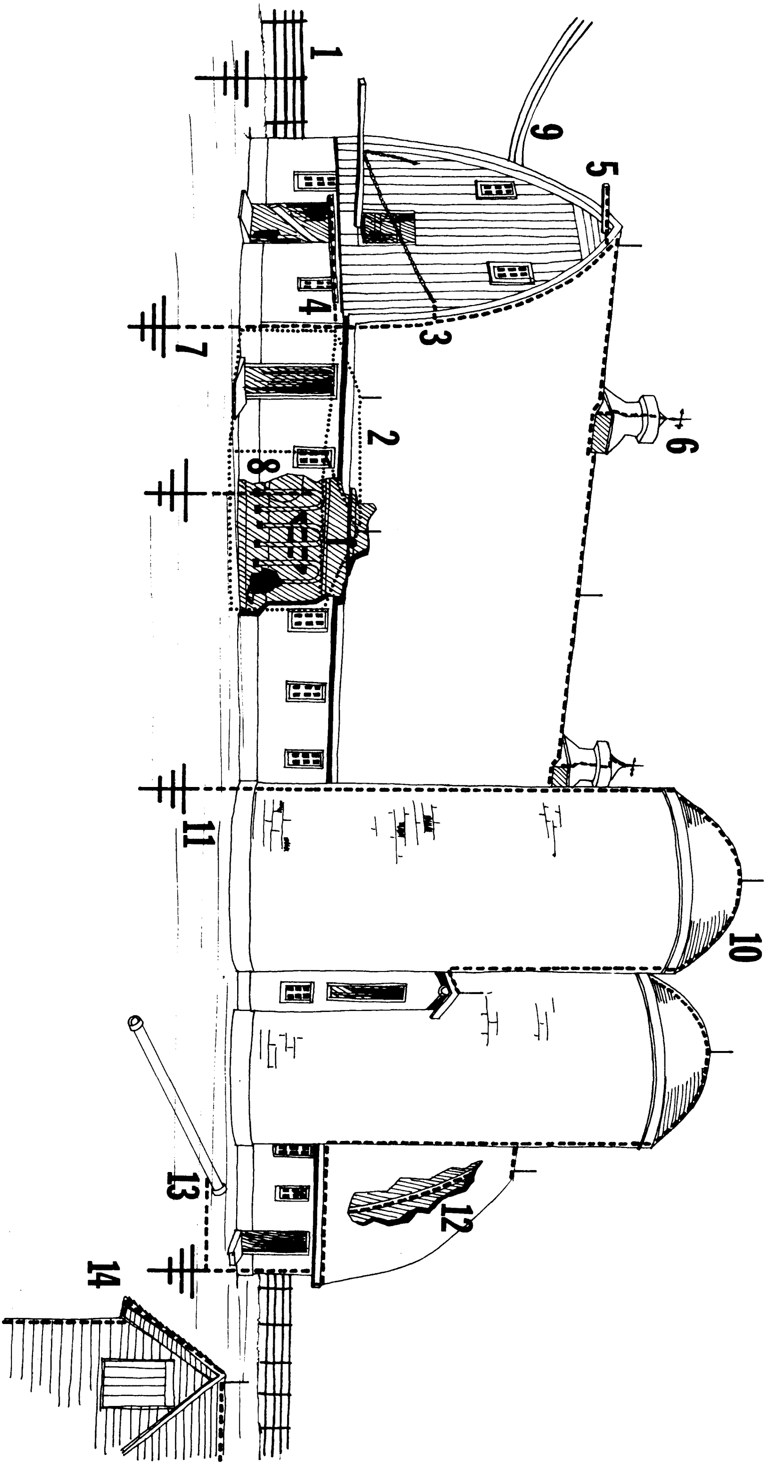
## Arresters

Lightning arresters should be installed between the power circuit and ground where the circuit enters any building served by overhead wires (fig. 11). Their purpose is to prevent dangerous surges of electricity into the building's wiring system when lightning strikes the power lines. Arresters should also be installed on television antennas.

An interior-type of lightning arrester that connects into the fuse box on the power supply side is also available.

Each arrester should be connected to the grounding system of the

*Figure 9.*—Lighting protection points for a barn: (1) Attached wire fence; (2) extension of system to an addition; (3), (4), and (5) branch conductors to litter, metal-door, and hay tracks; (6) terminals on cupolas, ventilators, etc.; (7) at least two grounds for barn; (8) tie-in of metal stanchions; (9) arresters on overhead wires; (10) at least one terminal on each domed silo and at least two on each flat-roof or unroofed silo; (11) grounded silo (if required); (12) connections to vents; (13) connections to water pipes; (14) protect all buildings—valuable or not—within 50 feet of barn.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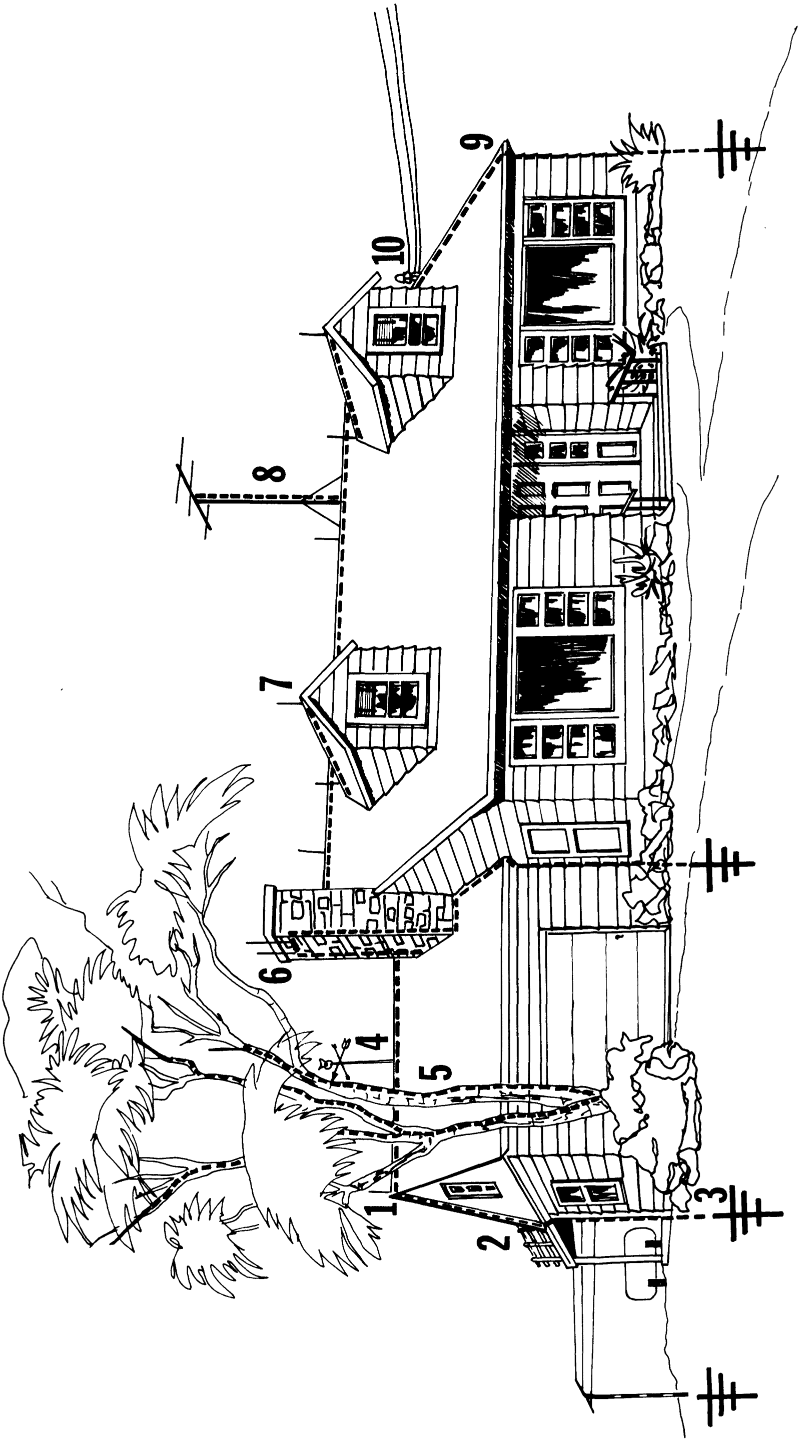
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building's lightning-protection system.

Arresters should be installed as part of new lightning-protection systems, and they should be added to existing systems to increase their effectiveness. They should be installed by an experienced lightning-protection specialist or a qualified electrician.

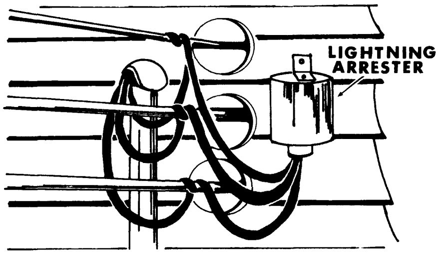


*Figure 11.*—Lightning arresters protect the building's electrical wiring system.

## Ground Connections

The ground connections are the key to the efficiency of the entire lightning-protection system.

At least two ground connections are needed for every system. They should be spaced as far apart as possible—preferably at opposite corners of the building—and should extend below and away from the building to prevent damage to the walls from lightning discharge.

Ground connections are made in one of four ways:

• By clamping the conductor cable to a copper-clad or galvanized-steel rod that has been driven at least 10 feet into the ground.

• By stranding copper conducting cable and burying it in a trench (fig. 12).

• By clamping copper conducting cable to a buried sheet metal plate (fig. 13).

• By clamping the conductor cable to a metal water pipe (fig. 14).

The chief requirement is to get a good, permanent connection between the lightning-protection system and moist earth. Never try to ground a system by putting a short length of a conductor cable into the earth; this does not give enough electrical contact.

Character of the soil in which a ground is to be made should be determined. Soil or chemical substances that may corrode ground connections should be avoided, if possible. Heavily galvanized steel resists corrosion for long periods in soil. Copper and copper-clad steel resist corrosion indefinitely in soil that is relatively free of ammonia. Aluminum corrodes in soil and should never be used for ground connections.

Moisture condition of the soil should be tested at various locations around the building, taking into consideration the dryness or wetness

*Figure 10.*—Lightning protection points for a house: (1) terminals spaced a minimum of 20 feet apart along ridges and within 2 feet of ridge ends; (2) downlead conductors; (3) at least two grounds, at least 10 feet deep, for house—additional grounds for clotheslines, etc.; (4) roof projections such as ornaments tied into conductor system; (5) protection for tree within 10 feet of house—connect to house grounding; (6) at least two terminals on chimneys; (7) dormers rodded; (8) arrester on antenna—connect to main conductor; (9) tie-in to conductor system of gutter withi 6 feet of conductor; (10) arrester on overhead power lines.

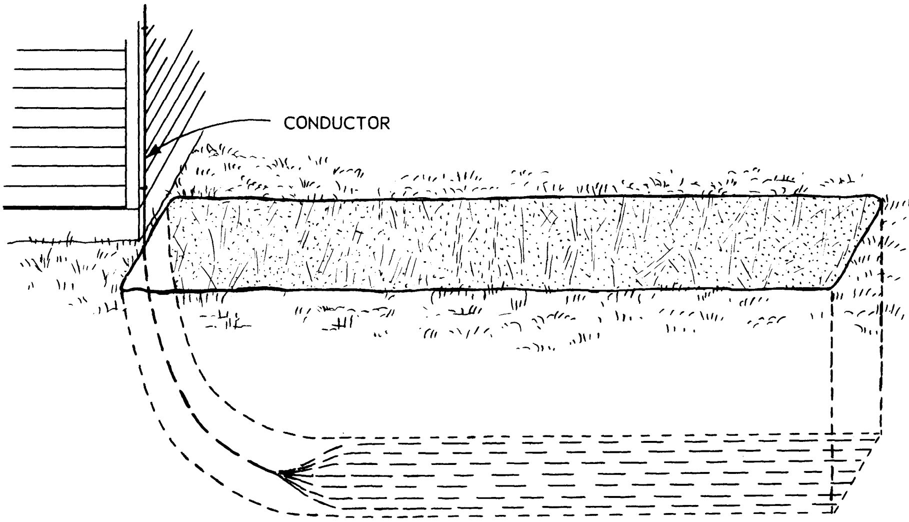


*Figure 12.*—**Ground made by burying a stranded conductor.**

of the season at the time. Ground connections should be made in the more moist locations.

If it is not practical to reach permanently moist earth, one of these methods should be used:

- Increase the area of the ground connection by extending the metal horizontally under the soil or by using several grounds extending radially away and downward from the point of entry into the ground.
- Increase the number of ordinary type ground connections.
- Run a full size copper conductor cable (counterpoise) completely around the building and connect all conductors to it.

Where soil conditions do not permit driving or digging to a sufficient depth, make a ground by burying a stranded copper cable in a trench. Follow these steps:

1. Dig a trench running away from the building. A trench 5 feet deep should be 15 feet long. One 4 feet deep should be 20 feet long. Shallower trenches should be proportionately longer.
2. Cover the trench floor with a 5-inch layer of pea-sized charcoal. This will help the grounding ability of the cable.
3. Untwist the cable and spread the strands over the charcoal. The ground may be improved even more by splicing another cable to the conductor cable near the point of entry into the ground, and then spreading additional strands in the same or another trench.
4. Cover the strands with another 5-inch layer of charcoal and fill in the trench with soil.

Connections to metal water piping where it enters a building generally make the best ground. The con-

nections should be made with a clamp designed for this purpose (fig. 14). Individual metal casings of the deep-well type, make excellent ground connections.

Aluminum conductor cable should be connected to copper or steel ground connections with bimetal clamps designed for this purpose; otherwise, the connections will corrode and render the system inoperative. These conductor-to-ground joints must be made at a point not less than 1 foot above grade level.

To prevent damage by livestock, protect conductors and ground con-

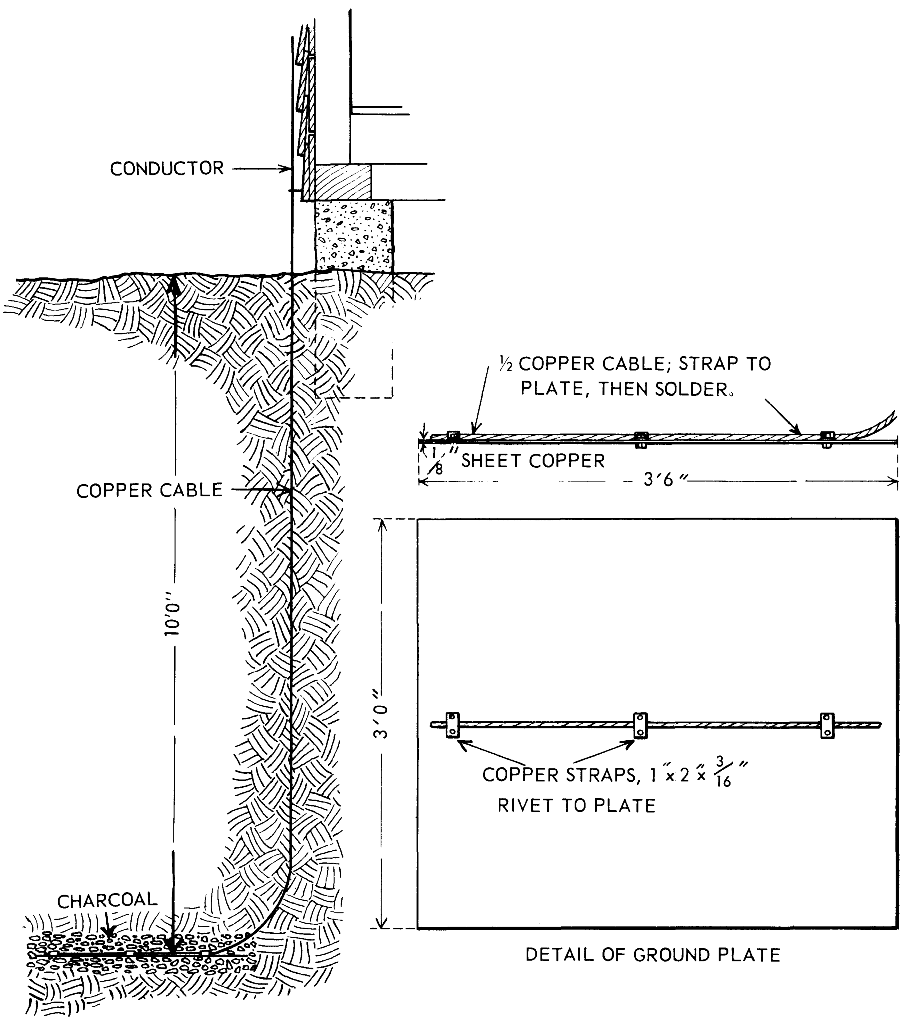


*Figure 13.*—Ground made by clamping a copper conducting cable to a buried sheet metal plate.

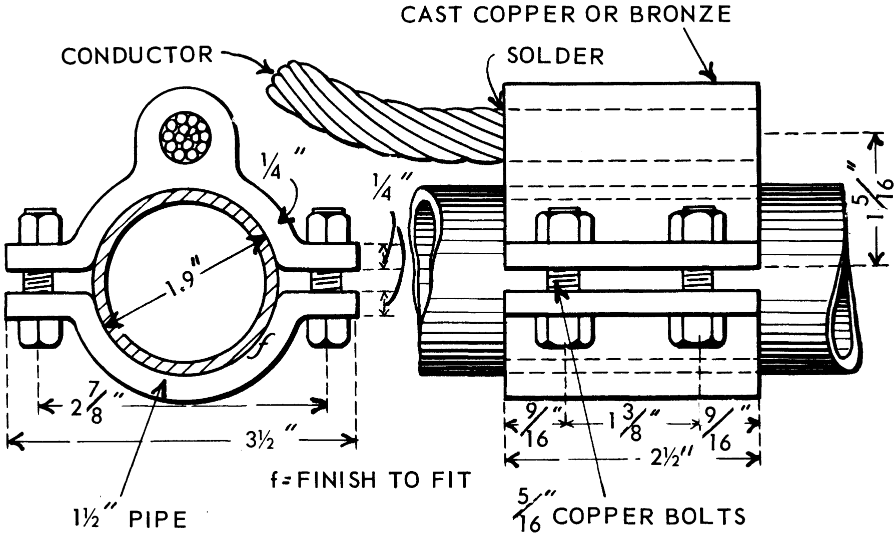


*Figure 14.*—Ground to a metal water pipe.

nections with wood, metal, or plastic guards at least 6 feet high.

After a ground connection is installed and connected with the whole system, it should be tested for electrical resistance. Any competent lightning-protection-system installer will have an instrument for testing grounds. Meter readings should be very low on the scale for a ground connection in good condition. Under 5 ohms is excellent, between 5 and 25 ohms is very good, and between 25 and 50 ohms is good.

## PROTECTION FOR LIVESTOCK

Lightning accounts for more than 8 out of every 10 accidental livestock deaths. The majority of these deaths occur where lightning protection is possible and can, therefore, be classified as preventable losses.

A 2-year study of 3,842 livestock *deaths by lightning* showed that 67 percent occurred in buildings, 20 percent under trees, and 6 percent along wire fences. Only 7 percent occurred in open pasture where the animals were a target and where lightning protection is not feasible.

In the same study, among cattle only, 38.5 percent died in buildings, 38.2 percent under trees, 6.2 percent at fences, and 17.1 percent at sites that could not be protected.

When lightning strikes a tree and kills cattle beneath it, death is not usually caused by the mainstream of the bolt; it is normally caused by current flowing through the animals standing or lying in direct contact with the charged ground.

To protect livestock:

- Install lightning-protection systems on barns and other major livestock buildings. (All major farm buildings should be protected for their own value.)
- Cut down, fence off, or protect isolated trees or small groves under which livestock congregate during storms. Value of the trees will determine the best procedure.
- Ground wire fences.

## PROTECTION FOR TREES

Trees may be ruined or severely damaged by lightning. If a tree is sufficiently damaged, it may fall on a building.

Trees that need lightning protection include those within 10 feet of any building, those under which livestock usually shelter during storms, and those that are valuable in themselves. Where there is a small grove of trees, only a few of the tallest need to be protected.

To protect a tree, install air terminals at the top of the trunk (or main branch) and at the end of main branches (fig. 15). Install the terminals as far out on the branches as it is possible to securely fasten them. Run the main conductor from the trunk terminal down to ground. Connect other terminals to the main conductor with branch conductors. Course the conductors along the trunk and branches. Trees with trunks more than 3 feet in diameter should have two down conductors.

To make ground connections, bury the conductor in a trench extending away from the tree at least 12 feet or to the extremity of the overhanging branches. The trench should be shallow near the tree to prevent damage to the roots. Ten-foot ground rods may be driven beyond the root spread.

To protect the exposed part of the conductor from damage by livestock, cover it with a suitable casing.

## GROUNDING WIRE FENCES

When lightning strikes an ungrounded or improperly grounded wire fence, some of the current may travel along the wires as far as 2 miles. This can be dangerous both to humans and livestock.

Wire fences that should be grounded include those attached to trees and buildings, those with wooden posts, and those with steel posts set in concrete.

Two ways to make satisfactory grounds are:

1. Use galvanized steel posts set into the ground, at intervals of 150 feet.

2. Drive ½- or ¾-inch steel rod or pipe 5 feet into the ground alongside wooden fenceposts at 150-foot intervals. Allow a few inches of the ground rod or pipe to extend above the top of each post. Fasten the rods or pipes to the posts with pipe straps so that they touch all the fence wires (fig. 16).

## INSPECTION AND MAINTENANCE

About 1 in every 30 reports of major farm-lightning losses spe-

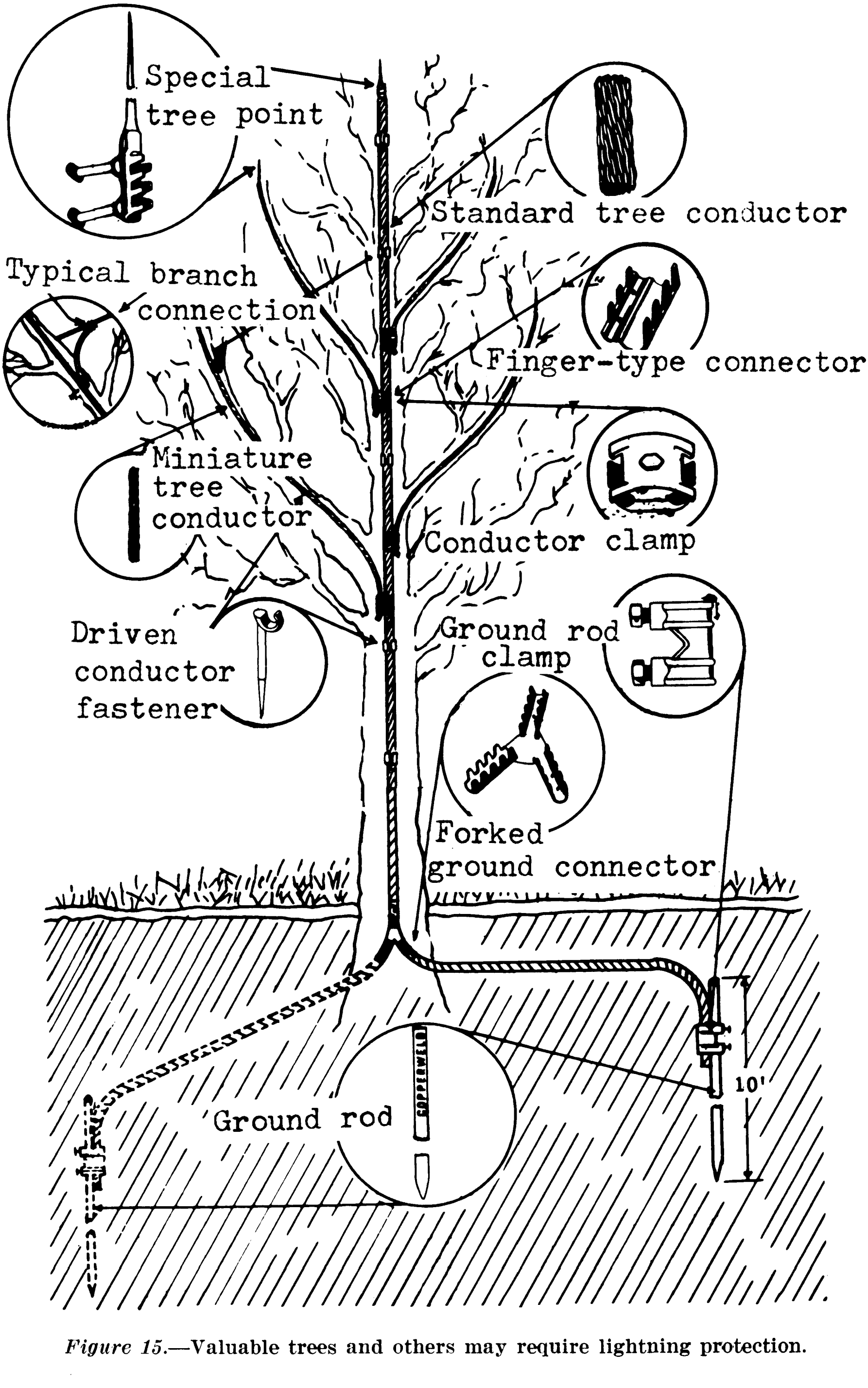


*Figure 15.*—Valuable trees and others may require lightning protection.

cifically mentions the existence of an old or improper lightning-protection system that failed to do the job. Many smaller "nuisance" losses occur because a branch conductor or a lightning arrester was not included in the system.

An old lightning-protection system should be inspected by a qualified lightning-protection dealer. Have him make the changes and additions necessary to meet the requirements for the Underwriters Laboratories' "Master Label." Extend the system to new buildings and to new additions to old buildings. Arresters should be installed as indicated on page 8.

Inspect a lightning-protection system every year. Check for bent, loose, or missing air terminals; broken conductor cables; and loose connecting clamps. You can arrange for a lightning-protection dealer to make this inspection automatically and make necessary repairs on the spot.

Lightning arresters should be checked periodically to determine the possibility of leakage of electrical energy. This check should be made by an electrician or other qualified person who has the proper equipment to measure the flow of current.

Inspect the lightning-protection system carefully whenever a building is re-roofed or re-sided.

## PERSONAL SAFETY

More people are injured by lightning in unprotected homes than at any other location. If your home is not protected, stay away from metal

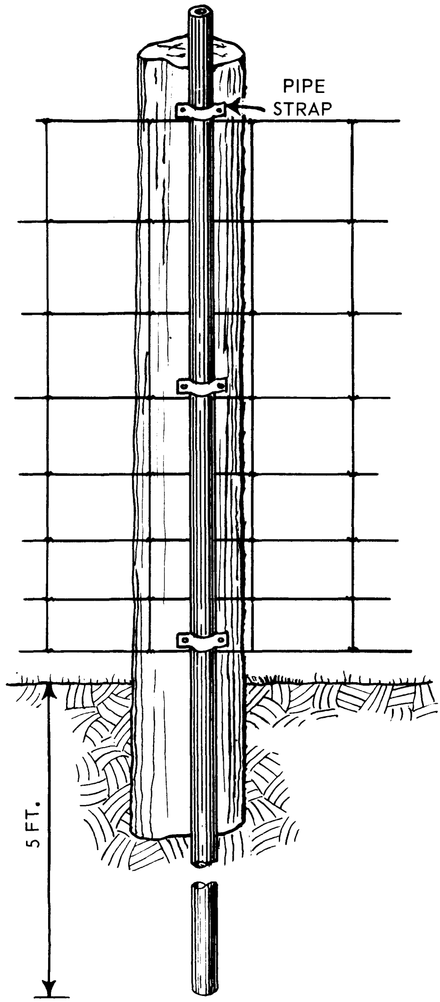


*Figure 16.*—**Wire fence grounded by driving a steel pipe into the ground.**

objects—prefabricated fireplaces, stoves, water faucets, appliances, the telephone, and metal windows—during an electrical storm.

Stay inside the house during an electrical storm. If caught outdoors, lie down in a low spot—in a ditch or depression—or under a rock ledge. Stay away from lone trees,

hilltops, wire fences, poles, and small unprotected buildings.

Remain in a closed truck or automobile during a storm. Do not ride a tractor, especially if attached equipment is in the ground. Riding in open vehicles or on horseback is very dangerous.



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